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(54) Method of manufacturing an electric discharge device

(57) In a method of manufacturing an electric discharge device comprising a pattern of metal electrodes 6 impressed into a glass plate 2 a metal foil 1 having a relief pattern and consisting of thick portions 6 constituting the desired pattern of electrodes 6 joined together by thin portions 7 is laid upon a glass plate 2, the foil 1 and plate 2 are heated to a temperature T_1 which is below the melting-point of the metal and at which the glass has a viscosity between 10^7 and 10^{13} Pa.S, and the foil 1 is pressed against the plate 2 so that the relief pattern is impressed into the glass in such a manner that there is intimate surface contact between the metal foil 1 and the glass plate 2 without gas inclusions. The electrodes 6 are then formed by removing the foil material constituting the thin portions 7.

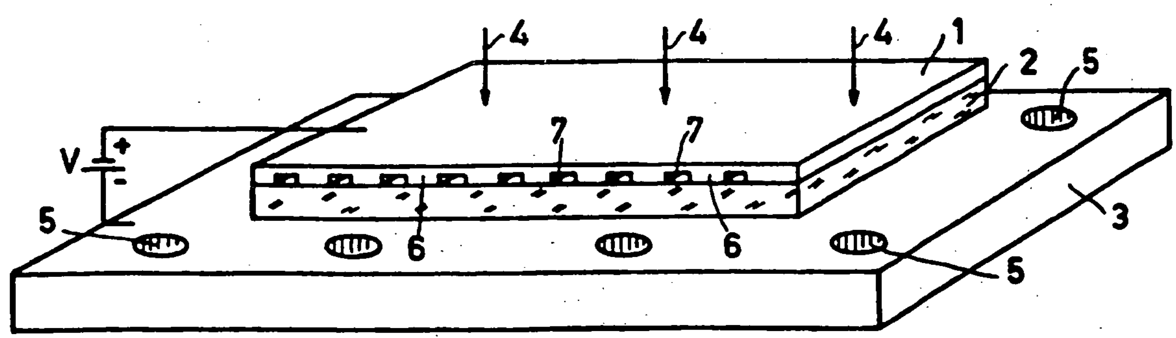

FIG.2

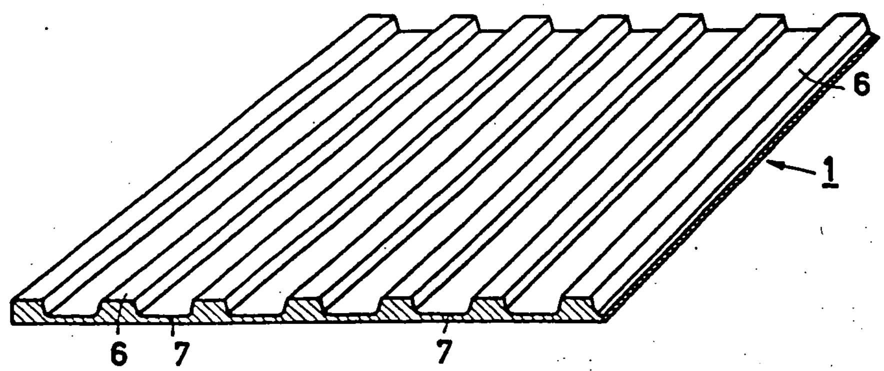

FIG.1

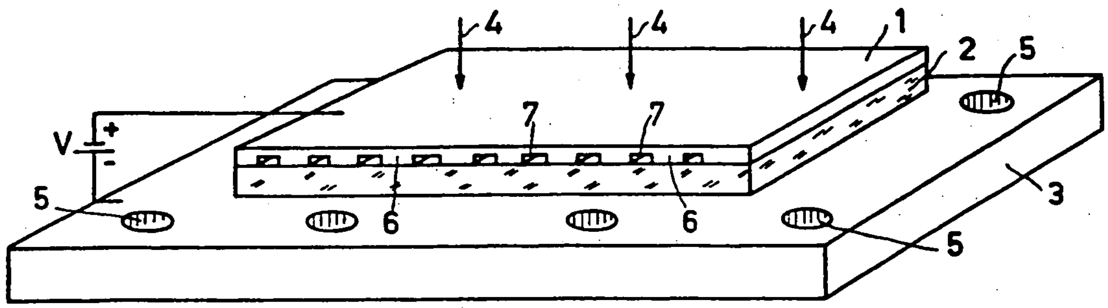

FIG.2

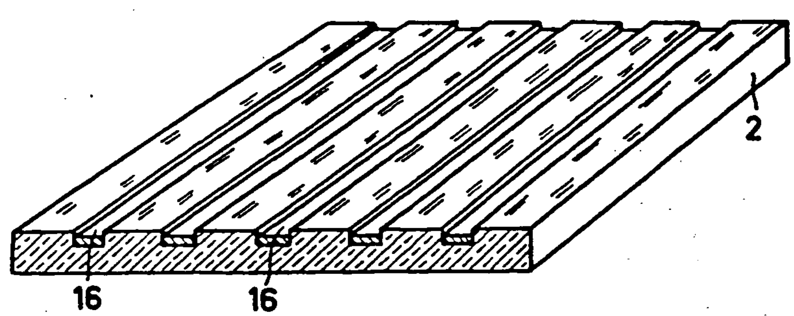

FIG.3

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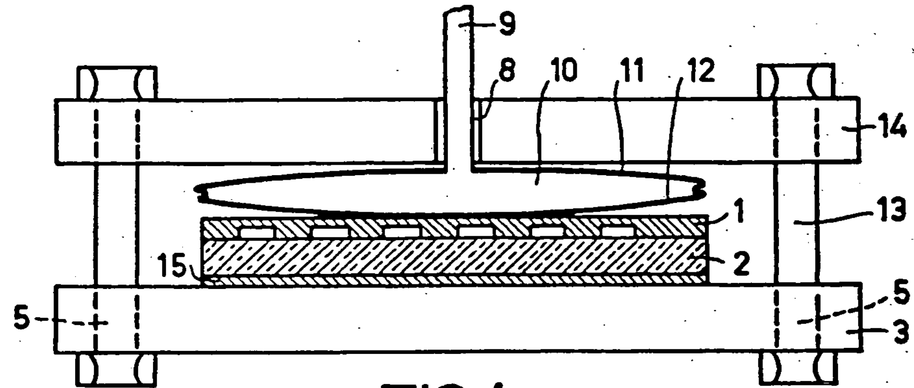

FIG.4

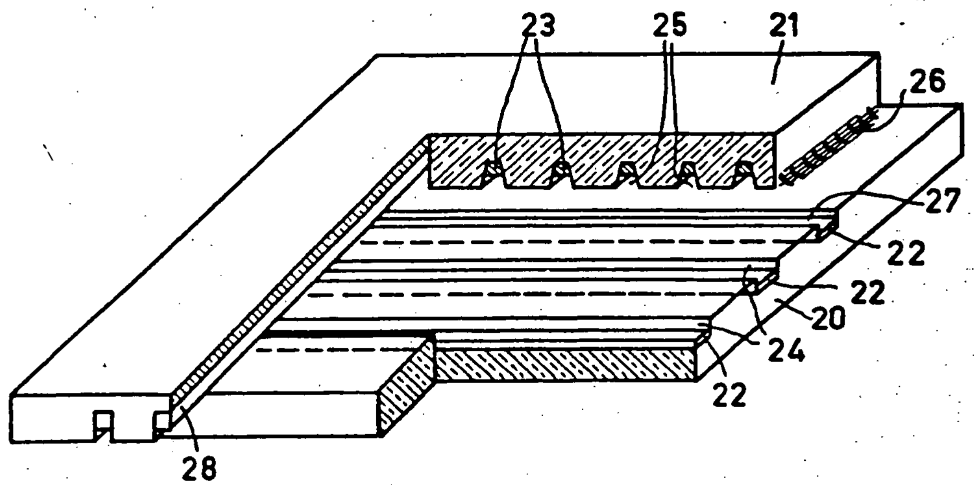

FIG.5

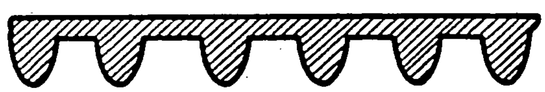

FIG.6a

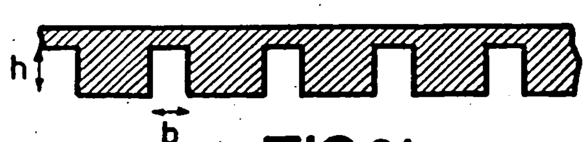

FIG.6b

SPECIFICATION

Method of manufacturing an electric discharge device

The invention relates to a method of manufacturing an electric discharge device comprising a pattern of electrodes impressed into a glass plate and to an electric discharge device manufactured by such a method.

United Kingdom Patent Specification 1,370,656 describes a method of manufacturing a gas discharge display panel, which panel comprises first and second panel plates of which the first is of a light-pervious material, each plate being provided with a number of mutually insulated parallel elongate conductors with the conductors of the second plate crossing the conductors of the first plate at an angle, all conductors being in contact with a gas atmosphere which is contained in cavities provided in parallel rows at the cross points of the conductors, in which method the cavities and the conductors are produced in at least one of said plates by providing a pressure plate in which cores corresponding to the cavities are immovably secued, the free end of each core having a groove therein which extends in the direction of the rows, placing each corresponding conductor in the grooves of a row of cores, and urging the pressure plate towards the panel plate after the latter has been softened, thereby forcing the cores and conductors into the softened panel plate, the pressure plate with its cores being then moved away from the panel plate to leave the conductors in the panel plate at the bottoms of the cavities produced by the cores. This known method is rather complicated, while there is a fair chance that damage is done to the glass plates, the electrodes and the pressure plate will be damaged when the pressure plate is moved away from the panel plate. Furthermore, the size accuracy of a pattern of electrodes obtained in this manner is not as good as is desired when, as if often the case, for example, in gas discharge display panels, a glass plate is to be provided with an extensive pattern of electrodes situated immediately beside each other.

It is the object of the invention to provide a method of manufacturing an electric discharge device, in which method a pattern of electrodes impressed into a glass plate is obtained in a simple manner and with great size accuracy

The invention provides a method of manufacturing an electric discharge device comprising a pattern of electrodes impressed in a glass plate, the method comprising the steps of taking a metal foil having a relief pattern consisting of thick portions which form the desired pattern of electrodes and are connected together by thin portions, placing the foil on a glass plate with the side of the foil comprising the relief pattern abutting the glass plate, heating the foil and glass plate to a temperature T_1 which is below the melting point of the metal and at which the glass of the glass plate has a viscosity between 10^7 and 10^{13} Pa.S, pressing the foil against the glass plate at the temperature T_1 so that the relief pattern is impressed into the glass in such a manner that there is intimate suface contact between the metal foil and the glass plate without gas inclusions, and producing the desired pattern of electrodes by removing at least the foil material constituting the said thin portions.

The great advantage of the method according to the invention is that the electrodes are not impressed individually into the glass plat but as parts of a coherent assembly, so that the mutual position of the electrodes is maintained. Furthermore, the method is fast and extremely suitable for mass production. The relief pattern is provided in the metal foil by means of known methods, for example, rolling, pressing, etching or spark erosion.

An intimate suface contact without gas inclusions between the metal foil and the glass plate can be produced in a simple manner by first pressing the metal foil against the glass plate over a restricted central area and then progressively applying pressure over an area extending towards the edges of the foil.

The extent to which the pattern of electrodes obtained according to the invention adheres to the glass plate often depends on the metal of which the metal foil consists. According to a further embodiment of the invention said adhesion can be improved after the relief pattern of the metal foil has been impressed into the glass plate by bonding the foil to the substrate by means of anodic bonding. This technique comprises the application of an electric potential difference across the parts to be joined at a temperature T_2, the surfaces to be bonded together of the parts being kept in intimate contact with each other. The temperature T_2 is chosen to be so high that the glass plate becomes slightly electrically conductive. During the bonding of the surfaces, these are kept in intimate contact with each other as a result of the electric potential difference by electrostatic forces, possibly supplemented by mechanical pressure.

Such a bonding method is disclosed *inter alia* in United States Patent Specification 3,397,278 and United States Patent Specification 3,589,905 the contents of which are deemed to be incorporated herein by reference. For further details regarding this bonding method reference is made to these Patent Specifications.

The metal foil may consist, for example, of copper, nickel, chromium, iron, or suitable alloys thereof. According to the invention an aluminium foil is preferably used since this

metal is easy to work mechanically and chemically.

According to a further embodiment of the invention an aluminium foil is used in combination with a soft-glass substrate, in particular a soda lime substrate. At a temperature T_1 of from 550 to 600°C, the aluminium foil is pressed against the soft-glass plate with a pressure of from 3×10^5 to 8×10^5 N/m^2, which results in a uniform contact between aluminium foil and glass plate. At a temperature T_2 of from 230 to 280°C, an electric voltage is applied across the glass substrate and the aluminium foil for at least three minutes, which results in a current of from 0.2 to 0.7 A/m^2 flowing through the glass, and produces a strong bond between the aluminium foil and the substrate. The desired pattern of electrodes is then obtained by etching away the thin portions of the foil.

The invention is of particular importance for the manufacture of gas discharge display panels, for example, gas discharge display panels the envelope of which comprises at least one glass plate on which a pattern of electrodes is provided. Such patterns of electrodes should be constructed from electrodes which are very accurately defined as regards mutual position and dimensions. The use of aluminium foil is preferred because aluminium is a metal which is easy to work. A pattern of aluminium electrodes provided in a glass plate according to the invention may be provided with an electrically insulating oxide film locally or entriely by means of anodic oxidation. By providing local electrically insulating oxide films on the electrodes using photoresist techniques accurately defined electrode regions not provided with such insulating films can be obtained, which is of importance for d.c.-operated display panels having a large resolving power. By providing the whole pattern of electrodes with an electrically insulating oxide film, a display panel can be obtained which can be a.c.-operated.

The invention also provides a solution of problems which occur when sealing the glass plates of display panels together in a vacuum-tight manner. Special measures had often to be taken, for example in the form of silver lead-through strips, to seal the panel in a vacuum-tight manner at the areas where the electrodes are led through. It has been found that such measures are not necessary in display panels manufactured by a method according to the invention. The bonding of the electrodes to the glass substrate is vacuum-tight and the sealing glass, often in the form of a "glass frit", produces a vacuum-tight seal both between th glass plates of the panel and also at the area where the electrodes are led through.

Some embodiments of the invention will now be described in greater detail by way of example, with reference, to the drawings, in which:

Figure 1 is a partly perspective view of a metal foil having a relief pattern,

Figures 2 and 3 illustrate the provision in a glass plate of a pattern of electrodes with the metal foil shown in Fig. 1,

Figure 4 is a diagrammatic side-sectional elevation of an apparatus for impressing a metal foil having a relief pattern into a glass plate,

Figure 5 schematically shows the construction of a gas discharge display panel having a pattern of electrodes, manufactured by a method according to the invention, and

Figures 6a and 6b are side-sectional elevations of two relief patterns.

The metal foil 1 shown in Fig. 1 is provided with a relief pattern by rolling, which pattern consists of a plurality of parallel ridges 6 which are joined together by means of thin portions 7. The metal foil 1 consists of aluminium and at the area of the ridges 6 has a thickness of approximately 200 μm, while the thin portions 7 have a thickness of approximately 100 μm. The relief pattern may be formed, for example, by spark erosion, by a photographic etching process, or by impressing it in the foil.

Fig. 2 illustrates the provision of the metal foil 1 on a glass plate 2 consisting of a soda-lime glass which consists essentially of 69.5% by weight SiO_2, 10% by weight Na_2O, 7.5% by weight K_2O, 10% by weight CaO, and 3% by weight BaO. With the relief pattern facing the glass plate, the assembly is laid on a stainless steel base plate 3 and heated in a furnace to a temperature T_1 of approx. 550 to 600°C. The soda lime glass at this temperature has a viscosity of approximately 10^{10} Pa.S. After the temperature T_1 has been reached, the metal foil is pressed against the glass plate 2 for 1 hour using a pressure of 5×10^5 N/m^2 in the direction of the arrows 4. The ridges 6 are pressed into the slightly softened glass until the thin portions 7 bear against the glass plate 2. The assembly thus obtained is cooled, after which the aluminium foil 1 is bonded to the glass plate 2 by means of "anodic bonding". This step in the manufacturing process is denoted diagrammatically by a voltage element V. The bonding process takes place at a temperature T_2 which is approximately 250°C and consists in applying an electric potential difference across the glass plate 2 and the foil 1 for 4 minutes, which potential difference results in an electric current of 0.5 A/m^2 flowing through the plate. The foil 1 thus bonded to the glass plat 2 is then subjected to an etching process, the top layer of the foil and hence including the thinner portions 7 of the foil being etched away completely. This operation forms a pattern of electrodes which consists of parallel electrodes (ridges 6), which pattern is sunk into the glass plate. Fig. 3 shows such a

pattern of electrodes in the glass plate 2, in which the exposed surface of the electrodes 16 is situated slightly below the upper surface of the glass plate 2, this construction being produced by subjecting the foil 1 to the etching process slightly longer than is necessary only for etching away the thin portions 7. The method described is extremely cheap and results in a pattern of electrodes satisfactorily bonded to the glass plate and having an accurate size.

Fig. 4 shows an apparatus used for pressing the relief pattern of the aluminium foil 1 into the glass plate 2 and which can produce a uniform contact between the aluminium foil 1 and the glass plate 2. By means of a number of bolts 13 which engage in threaded bores 5 in a base plate 3, a steel upper plate 14 is kept at a predetermined distance from the base plate 3. The upper plate 14 comprises a central aperture 8 through which a tube 9 extends. The tube 9 is connected to a pin-cushion-like expansion vessel 10 which consists of two metal diaphragms 11 and 12 which are sealed together in a vacuum-tight manner at their edges. The assembly formed by the glass plate 2 and the aluminium foil 1 is placed between the base plate 3 and the diaphragm 12. The tube 9 is connected to a compressed air apparatus not shown in the drawing whereby a pressure of 3×10^5 to 8×10^5 N/m^2 can be applied to the expansion vessel 10. When pressurizing the expansion vessel 10, the contact surface between the diaphragm 12 and the foil 1 will gradually be increased from the centre towards the edges of the foil 1. In this manner the formation of gas inclusions (gas bubbles) between the foil 1 and the glass plate 2 is avoided. A further aluminium foil is present between the base plate 3 and the glass plate 2. The foil 15 serves as an electric contact surface for applying the potential difference across the glass plate 2 and the aluminium foil 1 during the anodic bonding process. With the polarity indicated in Fig. 2, only the foil 1 comprising the relief pattern adheres rigidly to the glass plate 2. After the bonding process the aluminium foil 15 can be removed from the glass plate 2 quite easily.

The apparatus shown in Fig. 4 also makes it possible to simulataneously provide a number of glass plates with an aluminium foil. Each of the glass plates is provided with a superposed foil 1 and a subjacent foil 15 and stacked one on top of the other in the manner described with reference to Fig. 4 and the assembly is compressed at an elevated temperature. A chromium-nickel-iron plate covered on each major surface with a graphit layer or boron nitride layer is placed between each pair of opposed aluminium foils so that the otherwise abutting aluminium disposed between foils successive glass plates are prevented from being bonded together.

The method according to the invention is estremely suitable for use in the manufacture of gas discharge display devices. Fig. 5 shows the most elementary form of such a display device which includes a glass bottom plate 20 and a glass top plate 21. A pattern of strip-shaped aluminium electrodes 22 is provided in the bottom plate 20 by means of a method described above with reference to Figs. 1 to 4. The electrodes 22 constitute the cathodes of the display device. In an analogous manner the top plate 21 has been provided with a pattern of strip-shaped electrodes 23 which cross the electrodes 22 and constitute the anodes of the display device. Material has been etched away from the electrodes 22 and 23 to below the surfaces of the respective glass plates 20 and 21 so that channels 24 and 25 are obtained, the collective depth of which channels determines the spacing between the electrodes 22 and 23. The glass plates 20 and 21 are laid one on top of the other and are sealed together in a vacuum-tight manner at their edges by means of a sealing glass 26. The space between the plates 20 and 21 is filled with a suitable ionisable gas, for example, neon or a mixture of neon and argon. By applying a suitable potential difference between a cathode 22 and an anode 23, a glow-discharge is generated at the area where that anode and that cathode cross each other, which discharge is visible through the top plate 21. By scanning the anodes 23 and the cathodes 22 with a sufficiently high frequency in a predetermined sequence with voltage pulses corresponding to the display information, a display built up from discharge points can be displayed which is observed as an apparently continuous light picture. The display panel described here briefly is operated with direct current voltage. When the electrodes 22 and 23 consist of aluminium, the panel can be made suitable for a.c.-operation in a simple manner by providing said aluminium electrodes 22 and 23 with a thin electrically insulating oxide film by means of anodic oxidation.

It is alternatively possible to provide the cathodes 22 with an oxide skin with the exception of small regions at the area where the cathodes cross an anode. In this mann r, accurately defined discharge regions are obtained and a discharge panel of high resolving power can be manufactured.

As shown in Fig. 5, the electrodes 22 and 23 are provided with integrally formed extensions 27 and 28, respectively, so as to be able to apply the desired electric voltages to these electrodes. The invention provides a vacuum-tight adhesion of said extensions 27 and 28 to the glass plates 20 and 21, respectively. Due to this vacuum-tight adhesion, a vacuum-tight seal of the discharge panel is also obtained at the area of said extensions by means of the sealing glass.

Figs. 6*a* and 6*b* are side-sectional elevations of two possible forms of relief patterns. The relief patterns have been obtained by means of rolling, which has the advantage, as compared with etched patterns, that, as shown in Fig. 6*b*, the ratio *h/b* may be larger than one. This makes it possible to manufacture an electrode pattern having closely juxtaposed electrodes which have been impressed into the glass plate to a depth which is greater than the distance between adjacent electrodes.

CLAIMS

1. A method of manufacturing an electric discharge device comprising a pattern of electrodes impressed in a glass plate, the method comprising the steps of taking a metal foil having a relief pattern consisting of thick portions which form the desired pattern of electrodes and are connected together by thin portions, placing the foil on a glass plate with the side of the foil comprising the relief pattern abutting the glass plate, heating the foil and glass plate to a temperature T_1 which is below the melting point of the metal and at which the glass of the glass plate has a viscosity between 10^7 and 10^{13} Pa.S, pressing the foil against the glass plate at the temperature T_1 so that the relief pattern is impressed into the glass in such a manner that there is intimate surface contact between the metal foil and the glass plate without gas inclusions, and producing the desired pattern of electrodes by removing at least the foil material constituting the said thin portions.

2. A method as claimed in Claim 1, characterized in that intimate surface contact between metal foil and glass plate without gas inclusions is produced by first pressing the metal foil against the glass plate over a restricted central area and then progressively applying pressure over an area extending towards the edges of the metal foil.

3. A method as claimed in Claim 1 or Claim 2, characterized in that after impressing the relief pattern of the metal foil into the glass plate, the foil is bonded to the glass plate by means of anodic bonding.

4. A method as claimed any preceding Claim, characterized in that the metal foil consists of aluminium.

5. A method as claimed in Claim 4, characterized in that the glass plate consists of a soft glass.

6. A method as claimed in Claim 5, wherein the soft glass is a sodium lime glass.

7. A method as claimed in Claim 5 or Claim 6, characterized in that the aluminium foil is pressed against the soft glass plate at a temperature T_1 of from 550 to 600°C with a pressure of from 3×10^5 to 8×10^5 N/m^2, and the foil is bonded to the glass plate by means of anodic bonding by applying an electric voltage across the glass plate and foil for at least 3 minutes at a temperature T_2 of from 230 to 280°C, which voltage results in a current of from 0.2 to 0.7 A/m^2 flowing through the glass plate and the desired pattern of electrodes is obtained by etching away the thin portions of the foil.

8. A method of manufacturing an electric discharge device, substantially as herein described with reference to the drawings.

9. An electric discharge device manufactured by a method as claimed in any preceding Claim.

10. An electric discharge device as claimed in Claim 9, characterized in that it consists of a gas discharge display panel the envelope of which comprises at least a first glass plate in which an aluminium pattern of electrodes is provided.

11. A gas discharge display panel as claimed in Claim 10, characterized in that the envelope furthermore comprises a second glass plate in which a pattern of electrodes consisting of aluminium foil is also provided, which patterns of electrodes are provided with an electrically insulating oxide film.

12. A gas discharge display panel as claimed in Claim 10, characterized in that the pattern of electrodes is provided with an electrically insulating oxide film with the exception of small surface elements, which surface elements constitute surface parts of the pattern of electrodes active for a discharge.

13. A gas discharge display panel as claimed in any of Claims 10 to 12, characterized in that the first glass plate comprising the pattern of electrodes is bonded along a closed circuit to a second glass plate by means of a sealing glass, and the pattern of electrodes comprises extensions formed integrally therewith, which extensions cross the circuit of sealing glass and, at the area of such a crossing, on the one hand adhere directly to the glass plate and on the other hand adhere directly to the sealing glass so as to form a vacuum-tight electric lead-through for an electrode of the pattern of electrodes.

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